# Defense Technical Information Center Compilation Part Notice

# ADP013934

TITLE: Electromagnetic Modeling of the Jet Aircraft Intake with the Interior Impeller

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: 2002 International Conference on Mathematical Methods in Electromagnetic Theory [MMET 02]. Volume 2

To order the complete compilation report, use: ADA413455

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP013889 thru ADP013989

# ELECTROMAGNETIC MODELING OF THE JET AIRCRAFT INTAKE WITH THE INTERIOR IMPELLER

V.N. Kisel', A.I. Fedorenko

Russian Academy of Sciences, Institute for Theoretical and Applied Electromagnetics, 125412, ITAE, Izhorskaya 13/19, Moscow, Russia
E-mail: kis_v@mail.ru, kis@eldyn.msk.ru, fed@eldyn.msk.ru

## ABSTRACT

The 3D electromagnetic model of the aircraft intake terminated with blade structure is based on the utilization of equivalence theorem and integral expressions for electromagnetic fields. Acceptable numerical efficiency is achieved due to implementation of the special algorithm of successive electromagnetic field calculation trough the sectioned air duct from inlet aperture to the termination section and backwards. The equivalent surface currents over the apertures separating the sections and conducting walls are calculated iteratively in separate processes for each section, wall smoothness and large dimensions of the duct are taken into account to reduce computational cost. Rigorous integral equation technique exploiting rotational periodicity of the impeller is employed to treat the termination. Far field is evaluated via integrating currents over the intake aperture. Computed data are close to reference results (including experimental ones).

## ELECTROMAGNETIC MODEL DESCRIPTION

It is well known that scattering from engine intake of modern jet aircraft constitutes a main contribution to the total backscattered field at the front illumination aspects. The specific feature of the scattering is its dependence upon the properties of the intake loading to be the blade structure. Our previously reported results [1] referred to the developed 3D model based on the utilization of equivalence theorem and integral expressions for electromagnetic fields. Corresponding numerical techniques are highly time and computer memory consuming. To achieve sufficient computational efficiency the special algorithm of successive electromagnetic field calculation trough the sectioned air duct from inlet aperture to the termination section was developed and applied. Recently we found in literature analogous technique of duct subdivision [2], the main difference is that in our approach we have no need in evaluation scattering matrices of the duct sections. The surface currents over the apertures separating the sections, on the conducting walls and termination blades were calculated in the iteration processes. But further investigations revealed that when treating especially complex realistic termination sections (like impeller discussed below) the iterative physical optics (IPO) technique [3] tend to be divergent. So we turned to the rigorous integral equation (IE) approach in order to investigate the blade structure with the high precision. To make IE computer implementation suitable for the large (in terms of wavelength) real-sized blades we have exploited the rotational periodicity of the

scatterer resulting in the reduction of the computational domain to a single blade according to Prof. *E.N. Vasiliev's* ideas [4]. Similar approach was also discussed in literature (see, e.g. [5], where Green's function of the PEC circular waveguide was used). We applied Green's function of the free space that enabled us to solve corresponding electric field IE for a single blade $N$ times ($N$ being the number of blades rather than the number of circular waveguide modes) with respect to the unknown Fourier-harmonics of the surface currents. Besides, we preserved opportunity to account for presence of coating on the termination section walls. Galerkin's technique (moment method with the roof-top basis and testing functions defined on the rectangular cell grid) was used to convert IEs into the linear algebraic equation systems. Having defined scattering by the blades, the total scattered field was evaluated via the similar successive calculation of waves propagation through the sections of the duct from the termination to the inlet aperture. The reciprocity principle (see, e.g. [2]) was not applied since we took in mind the possibility of treating some other objects that might be placed into the duct, or cope with the specific properties of coating. Besides, while processing backwards, the contribution of wall current defined earlier (at "forward" propagation calculation) may be used to refine Kirchhoff's approximation. Far field is evaluated via integrating currents over the intake aperture. Possible coating of the interior walls was taken into account via its equivalent impedance and corresponding spatial, polarization and angular dependencies.

The communication discusses the accuracy and numerical efficiency of the approach comparing to IPO and pure PO treatment of the termination. Selected examples illustrating features of the technique are presented in Fig. 1 (comparison to modal expansion solution, [2]) and Fig. 2 (comparison to our experimental investigations of the model shown in Fig. 3); here calculated data are shown with solid curves. Example of numerical evaluation of the coating influence is depicted in Fig. 4 ($Z/W_0$=0.4-$i$0.3, $W_0$=120π, Ohms; note, section 4 remained uncoated).

## REFERENCES

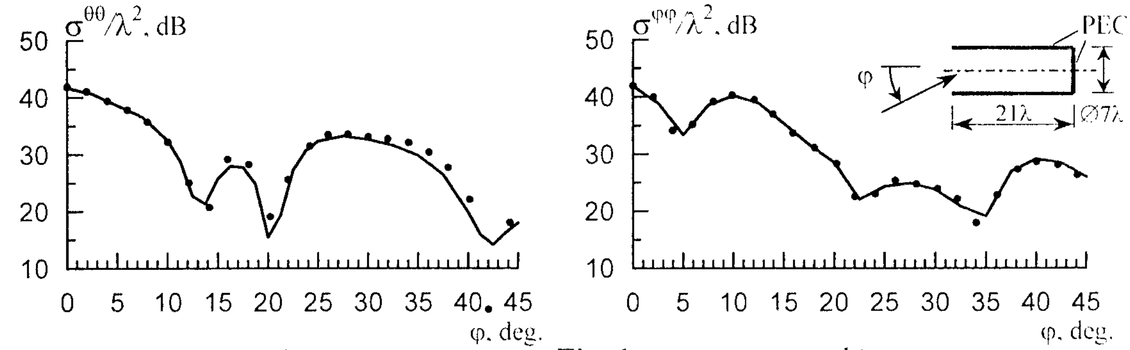

[1] V.N. Kisel', A.I. Fedorenko. Electromagnetic scattering from cavities with complex objects inside// Conf. Proc.: *2000 Int. Conf. on Math. Methods in Electromagn. Theory MMET2000,* Sept. 12-15, 2000, Kharkov. Ukraine. V. 2. P.447-449.

[2] F. Obelleiro, J. Campos-Nino, J.L. Rodriguez, A.G. Pino. A segmented approach for computing the electromagnetic scattering of large and deep cavities// *Progress in Electromagnetic Research,* PIER 19, 1998. P.129-145.

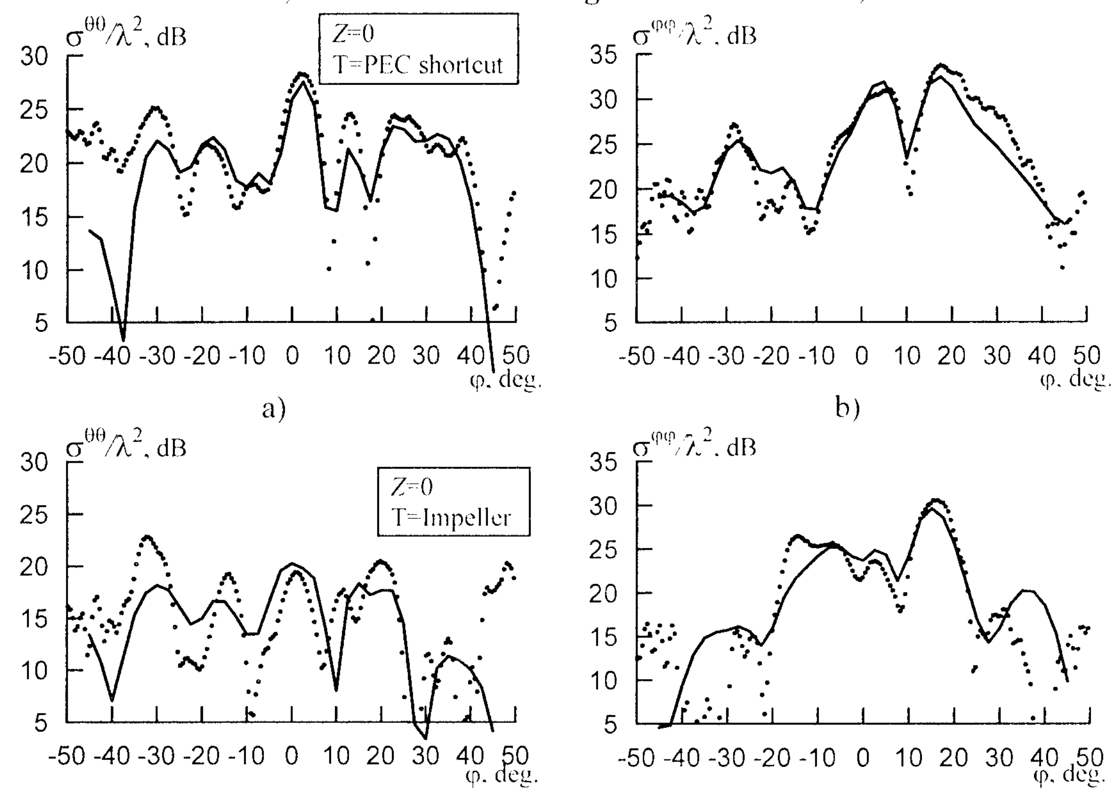
[3] F. Obeleiro-Basteiro, J.L. Rodrigues, R.J. Burkholder. An iterative physical optics approach for analyzing the electromagnetic scattering by large open-ended cavities// *IEEE Trans. Antennas and Propag.* V.AP-43. No.4. P.356-361. 1995.

[4] E.N. Vasiliev. Excitation of the bodies of rotation *(Vozbuzhdeniye tel vrascheniya) – in Russian.* - Moscow, Radio I Svyas', 1987. 272 p.

[5] H.T. Anastassiu, J.L. Volakis, D.S. Filipovic. Integral equation modeling of cylindrically periodic scatterers in the interior of a cylindrical waveguide// IEEE Trans. Microwave Theory Tech., V.MTT-46. No.11. P.1713-1720. 1998.




a) **Fig. 1** b)




c) **Fig. 2** d)

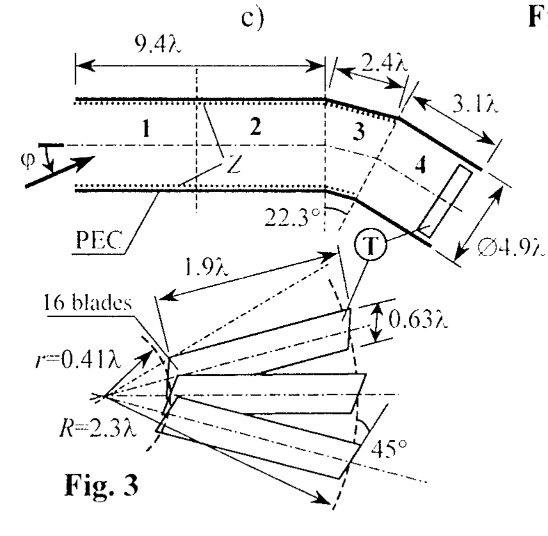



**Fig. 3**

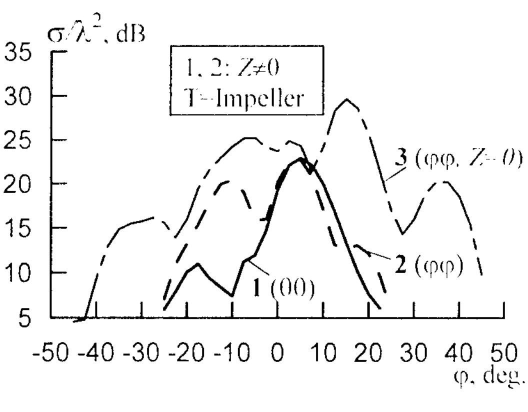



**Fig. 4**